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Assessment of the Potentials of Non-Edible Oils (Waste Cooking Oil, Neem Seed Oil and Castor Seed Oil) as Sustainable Feedstocks for Sustainable Biodiesel Production

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ABSTRACT

Conventionally, energy for transport and lighting is supplied via fossil fuels which are non-renewable and impact the environment negatively. As a result, the need for a clean alternative like biodiesel is essential. The cost of feedstock is a major barrier that faces biodiesel synthesis. Consequently, the search for a cost-effective oil feedstock for biodiesel production is crucial. The aim of this study was to carry out independent investigations on the suitability of waste cooking oil, neem seed oil and castor seed oil as renewable feedstocks for the production of biodiesel. To determine the values of the factors that determine their suitability, the three oils were characterized individually. The results showed that density, saponification value, acid value and free fatty acid content of waste cooking oil, neem seed oil and castor seed oil were 872.1, 900 and 905.5 kg/m^3, 235.66, 190.77 and 359.10 mg KOH/g oil, 6.49, 31.86 and 33.29 mg KOH/g oil and 3.25, 15.93 and 16.65% respectively. These values were similar to those available in published literature and showed that the three oils must first undergo esterification to make them suitable for biodiesel synthesis.

1. INTRODUCTION

The availability of energy is a very significant measure of the level of advancement of any nation (Amenaghawon et al., 2022). The rapid growth of population, urbanization, economy, and the developments in industrialization has brought about an increase in energy demand (Abbaszaadeh et al., 2012) and subsequently an increase in energy consumption worldwide (Tan et al., 2019). The major source of energy used to meet this demand is petroleum from fossil fuels. Fossil fuels are finite energy sources and they generate contaminants like sulphur oxides, carbon oxides, and some hydrocarbons (HCs) during combustion (Ayoola et al., 2020). These contaminants are associated with global warming and climate change (Aransiola et al., 2014).

As a result of the problems associated with the use of fossil fuels, recent focus is on the use of renewable sources of energy which can help to address the issues faced by fossil fuels. Biodiesel has attracted the attention of researchers as a clean alternative source of energy as a result of its usefulness over petro-diesel which includes its low viscosity, biodegradability, renewability, and non-toxicity (Betiku et al., 2019; Nayebzadeh et al., 2016).

Transesterification is the process used in biodiesel synthesis and it involves the reaction of triglycerides found in either edible or inedible oils/fats and an alcohol (Cardoso et al., 2020). The reaction is carried out either in the presence or absence of a catalyst with glycerol produced as a byproduct (Amenaghawon et al., 2022; Baskar et al., 2017; Changmai et al., 2020). A major factor that contributes to the high production cost of biodiesel is the type of feedstock used in the production process. Studies have shown that feedstock accounts for between 80 and 85% of the total production cost of biodiesel (Betiku et al., 2019). To this end, recent research is centered on the use of non-edible oils such as neem seed oil (Akhabue et al., 2020), rubber seed oil (Sudalaiyandi et al., 2021), castor seed oil (Paul et al., 2021), Jatropha curcas seed oil (Ewunie et al., 2021), *Hura crepitans* seed oil (Adewuyi et al., 2014), waste animal fat (Azadbakht et al., 2021), and waste cooking oil (Amenaghawon et al., 2021; Yusuff et al., 2021) amongst others as feedstocks primarily because of their economic advantage (Changmai et al., 2020).

With regards to this study, the focus is on waste cooking oil, neem seed oil and castor seed oil. Waste cooking oils are obtained from edible vegetable oils that have been used in frying food. They are generated largely from restaurants and catering services in Nigeria. Disposal of these wastes constitutes a serious problem as they usually accumulate in the drainage system and cause contamination of water bodies (Yusuff et al., 2021). To address these drawbacks, a practicable option would be their use as oil feedstocks in biodiesel synthesis (Amenaghawon et al., 2022). Neem belongs to the mahogany family Meliaceae, usually known as Nimtree, or India Lilac. It originated from India but can be found growing in the tropics of Africa like Nigeria and is considered a weed in many countries. Neem seed oil constitutes about 25–47% of the neem seed and it is considered to be the most readily available product of the neem plant. Neem seed oil can either be produced mechanically (by the hot or cold process) or chemically by solvent extraction from the dried neem seed (Banu et al., 2018). Castor oil is obtained from castor seeds which are native to some areas in Nigeria (Tochukwu Vincent, 2024) and is considered the world over to be an economically significant oil crop (Phewphong et al., 2024). Their plants grow very quickly and are frequently seen as softwood trees. They also have the capacity to survive in areas with very harsh weather which can be unsuitable for the growth of other crops. Castor seeds usually have high oil yields (40-55%) and are nonedible and so can be used in biodiesel production (Fareed et al., 2024).

For an oil to be considered suitable for biodiesel synthesis, it must exhibit certain acceptable physical and chemical properties. As a result, the focus of this study was to examine the physical and chemical properties of waste cooking oil, neem seed oil and castor seed oil to establish their feasibility as oil feedstocks in biodiesel production.

2. MATERIALS AND METHODS

2.1. Raw materials and Reagents

The waste cooking oil was sourced from local eateries in Benin City, Edo State, Nigeria while Neem and Castor seed oils were sourced from a local vendor in Niger State, Nigeria. In this study, all chemical reagents used were produced by BDH Chemicals Ltd., located in Poole, England, and were of analytical grade.

2.2. Preparation of Oils

To reduce the levels of moisture present in the oil, waste vegetable oil was heated to 120°C after being filtered through a muslin cloth to remove food particles and water. Thereafter, the oil was characterized.

The Castor seed oil was heated at 120°C in order to reduce its moisture content prior to its characterization. Neem seed oil was preheated to 120°C to remove excess moisture before analyzing its properties.

2.3. Characterization of Oils

Assessment of the suitability of waste cooking oil, neem and castor seed oils as oil feedstocks for biodiesel production was carried out by examining their physicochemical properties through suitable characterisation techniques. Colour, iodine value, physical state, specific gravity, moisture content, density, average molecular weight, acid value, free fatty acid, and saponification value were some of the properties that were studied. The colour and physical state were examined by physical inspection. ASTMD1298 and ASTMD2709 (Fernando et al., 2007) test methods were used to examine the density and moisture content of the oil respectively. In order to determine the specific gravity of the oils, a density bottle used. In the same vein, ASTM D664 (Wang et al., 2007) and ASTM D1962 Thangarasu & Anand, (2019) test methods were used to determine the acid value and saponification value of the oils respectively.

3. RESULTS AND DISCUSSION

3.1. Physicochemical Characteristics

Table 1 shows the results obtained upon characterization of waste cooking oil, neem seed oil and castor seed oil. Upon physical observation, it was seen that the three oils were liquid at room temperature and while waste cooking oil was light yellow in colour, neem and castor seed oils were each dark brown in colour. The moisture content of Waste cooking oil (WCO), Neem seed oil (NSO) and Castor seed oil (CSO) were determined to be 0.4, 0.94 and 0.64% respectively. This is similar to results obtained by Alias et al., (2018) and lower than that reported by Taiwo et al., (2020). The knowledge of the moisture content of oil feedstocks is essential as a high level if present, might reduce the effectiveness of the catalyst, contribute to microbial growth and reduce the quality of the biodiesel produced amongst others (Rocha-Meneses et al., 2023). The free fatty acid content of waste cooking oil, neem seed oil and castor seed oil were found to be 3.25, 15.93 and 16.65% respectively. These are similar to results obtained by Onyezeka et al., (2020) and Adamu Zubairu Utono et al., (2024). The free fatty acid of an oil is influenced by the method of purification (Sahar et al., 2018). Worthy of note is that a rise in the free fatty acid/acid value may speed up the deterioration of rubber components in engines, cause corrosion in the internal combustion engine, and clog filters as a result, it is essential for the values obtained in this study to be reduced via esterification in order for these oils to be suitable as feedstocks for high quality biodiesel production (Rekhate and Prajapati, 2019; Singh et al., 2022).

Table 1: Properties of waste cooking oil, neem seed oil and castor seed oil

Properties	WCO	NSO	CSO
Colour	Light yellow	Dark brown	Dark brown
Physical state at room temperature	Liquid	Liquid	Liquid
Moisture content (%)	0.40	0.94	0.64
Acid value (mg KOH/g oil)	6.49	31.86	33.29
Free fatty acid (%)	3.25	15.93	16.65
Saponification value (mg KOH/g oil)	235.66	190.77	359.10
Density @ 40°C (kg/m^3)	872.1	900	905.5
Specific gravity	0.8721	0.900	0.9055

Furthermore, combining the three oils could help in balancing fatty acid composition and improving the properties of the fuel produced (Oyedoh et al., 2024). The saponification values of waste vegetable oil, neem seed oil and castor seed oil obtained in this study are 235.66, 190.77 and 359.10 mg KOH/g oil respectively. This is similar to findings by Nwanekezie et al., (2023) and Taiwo et al., (2020) and lower than that obtained by Mustapha et al., (2024). Saponification value gives an estimate of the percentage of fatty acids present in the oil/fuel (Onu and Mbohwa, 2021). High levels of fatty acids suggest a high likelihood of saponification during the transesterification reaction, which makes the separation of final products following biodiesel synthesis difficult (Sasongko et al., 2017). ASTM standard for saponification value of an oil/biodiesel states that the value should be between 0 and 370 mg KOH/g (Singh et al., 2019). The values obtained in this study for the three oils under review show that they were all below 370 mgKOH/g oil and so are suitable oil feedstocks for biodiesel production. The specific gravities of waste cooking oil, neem seed oil and castor seed oil were determined to be 0.8721, 0.900 and 0.9055 respectively while their densities were evaluated as 872.1, 900 and 905.5 kg/m^3 respectively. Density is an essential property when considering oils to be used for biodiesel production as it affects its performance in the diesel engine (Devarajan and Selvam, 2024; Husaini et al., 2024).

The values obtained in this study were lower than the values obtained by Amenaghawon et al., (2022) who obtained a density of 971 kg/m^3 for waste cooking oil, Fredrick et al., (2023) who obtained a specific gravity of 0.922 for castor seed oil and Garba et al., (2024) who obtained a specific gravity of 0.94 for neem seed oil. For an oil feedstock to be suitable in biodiesel synthesis, its density and specific gravity must fall within 860-900 kg/m^3 and 0.86-0.9 respectively (Onu and Mbohwa, 2021). The three oils under study fall within this range and so are suitable for use in biodiesel production.

4. CONCLUSION

The suitability of waste cooking oil, neem seed oil and castor seed oil as oil feedstocks for sustainable biodiesel production was investigated in this study. The results obtained from all the tests carried out show that waste cooking oil, neem seed oil and castor seed oil are suitable feedstocks for biodiesel production although they will have to undergo esterification prior to biodiesel production. The used of these oils is expected to make biodiesel production a more cost-effective process.

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6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

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